Is the African armoured searobin (*Peristedion cataphractum*, Peristediidae) stock off the south Sicily and North African coasts a "unit stock"?

by

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ABSTRACT. - Distribution, abundance, biological traits and growth of *Peristedion cataphractum* L., 1758 coming from two areas of the Strait of Sicily were analysed. The two investigated areas correspond to the north (A-area) and south (B-area) of the midline located between South Sicily and North Africa. Both published and new elaborated parameters were estimated from data gathered in autumnal experimental bottom trawl surveys; the surveys in the B-area, in particular, were carried out between 1997 and 2004. The abundance resulted to be ten fold higher in the B- than in the A-area. The biological parameters ranges resulted in 0.38-0.48 and 0.42-0.50 (sex ratio), 200-230 and 200-225 mm (median total length of mature stage), 200-232 and 200-222 mm (mean total length of mature stage) and 168-221 and 177-199 mm (size at 50% of sexual maturity) for stocks from A and B areas, respectively. The length frequency distributions were always significantly different. The von Bertalanffy growth function (derived after sex combined length frequency analysis) revealed a high closeness: 379-390 mm and 0.38-0.36 for L_∞ and K_y^{-1}, respectively. These results support the hypothesis of a common genetic-biological features of the population on one side, but also suggest maintaining them operationally distinct (i.e., as "unit stocks" *sensu* Gulland) since the likely low rate of spatial interchange (as a consequence of the low mobility of this species) and the reported differential in fishing exploitation.

RÉSUMÉ. - La population du malarmat africain (*Peristedion cataphractum*, Peristediidae) de la partie sud de la Sicile et des côtes d'Afrique du Nord est-elle un "stock unité" ?

La répartition, l'abondance, les traits biologiques et la croissance de *Peristedion cataphractum* L., 1758 provenant de deux zones du détroit de Sicile ont été analysés. Les deux zones correspondant au nord (zone A) et au sud (zone B) de la ligne médiane située entre le sud de la Sicile et l'Afrique du Nord ont été étudiées. A la fois les paramètres publiés et ceux qui sont nouvellement élaborés ont été estimés à partir des données recueillies lors des campagnes expérimentales au chalut de fond d'automne ; les campagnes dans la partie sud de la zone d'étude, en particulier, ont été réalisées entre 1997 et 2004. L'abondance calculée s'avère être dix fois plus élevée dans la zone B que dans la zone A. Les gammes de paramètres biologiques s'échelonnent de 0,42-0,50 à 0,38-0,48 (pour la sex-ratio), entre 200-230 et 200-225 mm (pour la médiane de la longueur totale de la phase de maturité), entre 200-232 et 200-222 mm (pour la longueur moyenne de la phase de maturité) et entre 168-221 et 177-199 mm (pour la taille à 50% de la maturité sexuelle), respectivement pour les stocks des zones A et B. Les distributions de fréquence de taille ont toujours été significativement différentes. Les fonctions de croissance de von Bertalanffy (dérivées d'après les analyses de fréquences des longueurs des sexes combinés) sont très proches: 379-390 mm et 0,38-0,36 respectivement pour L_∞ et K_y^{-1}. Ces résultats confortent l'hypothèse de caractéristiques communes génétiques et biologiques des stocks dans les deux zones et suggèrent aussi le maintien d'une distinction sur le plan opérationnel (au sens de "stock unité" de Gulland) en raison d'un faible taux d'échange dans l'espace (conséquence de la faible mobilité de cette espèce) et des différences notées dans l'exploitation de la pêche.

Key words. - Peristediidae - *Peristedion cataphractum* - Central Mediterranean Sea - Bottom trawl fishing impact - Biological comparison - Unit stock.

The concept of "stock" is fundamental for the study of the dynamics of exploited living aquatic resources. There are many ways of defining a stock and no general agreement about this item. In the context of fish stock assessment and management, a more operational definition was proposed by Gulland in 1983, i.e., any sub-group of a given species can be treated as a unit stock when possible differences within the group and interchanges with other groups can be ignored, without making the conclusions reached invalid. It is worth noting that adopting the Gulland's criterion, even males and females of the same population can be treated as different unit stocks when sexual dimorphism and sex-specific fishing pattern exist.

Notwithstanding the relevance of unit stock and stock interaction items, both of them are still poorly defined within the Mediterranean fisheries (Lleonart and Maynou, 2003)

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especially for those species considered as by-catch and less studies such as *Peristedion cataphractum* L., 1758.

This species named as African armoured searobin is a gregarious, sedentary, bottom dwelling fish distributed in the Eastern Atlantic (from the British Isles to Angola) and the Mediterranean Sea (Froese and Pauly, 2011). It occurs preferably on muddy bottoms between 50 m and 848 m (max reported depth) with a peak in density on the continental slope (410 m) (Katsanevakis and Maravelias, 2009; Bottari *et al*., 2010). Close to family Triglidae to which the species was included in the past, the African armoured searobin belongs to the family Peristediidae. Most of information on this species come from the Mediterranean Sea and regard eggs and larvae (Doderlein, 1879; Emery, 1886; Spartà, 1947), general features (Tortonese, 1975), and morphometrics estimations (Munoz-Chapuli and Blanco Ruiz, 1980; Filiz and Bilge, 2004). The spawning occurs from May to October (Mytilineou *et al*., 2004; Bottari *et al*., 2010). It feeds mainly of Crustaceans (Mysidacea) and Mollusca.

The growth rate is high (70-60 mm.y^{-1}) till 1.5-2 years of age, decreasing once sexual maturity is started and sexual maturity achieved between 190-210 mm of length (L_m), around 2-3 years of age (Bottari *et al*., 2010). The growth pattern is coherent with the growth patterns of the Mediterranean searobins (Papaconstantinou, 1986; Colloca *et al*., 2003; Ragonese and Bianchini, 2010).

The African armoured searobin was historically considered as a common widespread findings and most recurrent catch on the grounds located off the South Sicily and the North African coasts (Bourgois and Farina, 1961; Arena, 1985); a recent study (Bottari *et al*., 2010), however, highlighted the rarefaction of the species off the South Sicily and some local high abundance spots close to the North African borders.

The lack of knowledge about the identification of separate Mediterranean populations (if any) for this species, makes impossible to evaluate objectively the degree of match-mismatch among the stock (from an operational point of view) and geographical subareas which have been implemented for management purposes in the Mediterranean at the end of nineties (GFCM, 2001, 2009).

In this paper, the hypothesis of unit stock is tested by comparing abundance and biological features of *P. cataphractum* coming from two contiguous areas of the Strait of Sicily (Central Mediterranean Sea).

MATERIALS AND METHODS

Published (Bottari *et al*., 2010) and new elaborated parameters derived by data concerning the African armoured searobin and gathered in six bottom trawl surveys carried on between 1997 and 2004 (Tab. I) were compared. In particular, the published and new elaborated parameters refer to the grounds located in the north (A-area) and south (B-area) of the midline between South of Sicily and North Africa (Fig. 1). The former has been traditionally considered more heavily exploited than the latter, especially from Mazara del Vallo trawl fishery, which is one of the most important in the Mediterranean Sea (Levi *et al*., 1998; Garofalo *et al*., 2003; Gristina *et al*., 2006; Dimech et *al*., 2008).

As regards the hydrological features, three main water layers are traditionally recognized (Sardà *et al*., 2004; Ragonese *et al*., 2008): the Atlantic Waters (down to 50-100 m or to 150-250 m, depending on locations) with a minimum water temperature of 14-15°C in winter; the Levantine Intermediate Waters (down to 500-700 m), where the temperature goes down to about 13-14°C; and a deep

Table I. - Number of hauls and specimens of *Peristedion cataphractum* by survey and area.

Survey N°	Year	N° of valid hauls		N° of specimens	
		Area A	Area B	Area A	Area B
1	1997	83	177	1296	16490
2	1998	82	176	984	20390
3	2000	67	170	604	10001
4	2001	68	169	1030	11995
5	2003	116	83	1464	3686
6	2004	78	94	609	5186

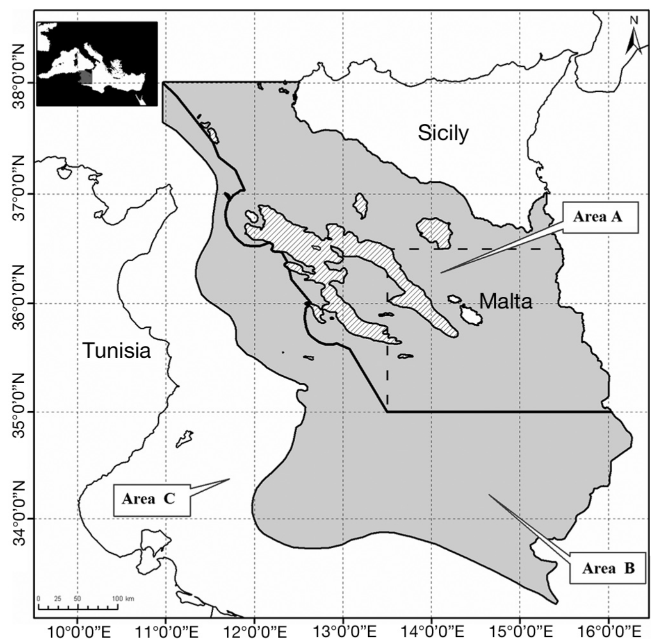

Figure 1. - Map of the study area according to IAMC-CNR classification. Experimental bottom trawl surveys were conducted in the north (A-area) and south (B-area) grounds of the midline. The C-zone was never explored by IAMC-CNR staff. Presently, the north area includes two GFCM geographical subareas (limited by the dotted line).

transitional layer (below 600-700 m; 12.8°C).

A depth-stratified sampling design was adopted to gather data and the sampling hauls were randomly allocated within the strata according to an area-proportional criterion. Sampling at sea has been conducted with a commercial trawler (32.2 m length overall; powered with a 736-kW engine). The net had 20 mm-diamond stretched mesh size in the codend; the vertical opening was ca. 0.6-1.3 m.

Daytime (30 minutes before dawn and after dusk) hauls lasting 0.5-1 h were performed. The haul catch was sorted for the African armoured searobin, the overall abundance in weight and number was recorded and the corresponding biological material was frozen at -40°C on board. Then, in laboratory, each sampled specimen was defrosted overnight, measured (total length, TL; mm) and sexed. Macroscopic maturity stage was assigned in accordance with Holden and Raitt scale (1974). Specimens were classified in: 1st, immature; 2nd, immature/developing or recovering; 3rd, maturing; 4th, fully mature and 5th, spent or resting.

As the African armoured searobin occurred preferentially in the upper slope bottoms (201-500 m) (Katsanevakis and Maravelias, 2009; Bottari *et al*., 2010), mean density index (DI: N*km^{-2}), biomass index (BI: kg*km^{-2}) and frequency of occurrence (f, computed as percentage of positive hauls) were estimated and compared only for this depth range.

The DI by haul were interpolated and mapped by the GIS software ArcMap^{TM} 9.0 (ESRI). An "exact interpolator" procedure (Inverse Distance Weighting) was used (Isaaks and Srivastava, 1989).

The following biological parameters were estimated according to the same methodologies in Bottari *et al*. (2010): sex ratio (Sr), defined as the proportion of females F on the total sexed individuals ($F + M$), median and mean length of fully mature specimens, and the size at the onset of sexual maturity (L_m, derived according to the logistic approach).

As concerns the length based analysis, individual lengths were combined by survey time period in 10 mm class width and the resulting length frequency distribution (LFD) analysed with LFDA 5 software (Hoggarth *et al*., 2006).

The Shepherd's Length Composition Analysis (SLCA; special VBGF-von Bertalanffy Growth Function) was implemented starting from seed values sets available (Bottari *et al*., 2010). The best model was established on the base of the LFDA score function, which measures the goodness of fit of the length frequency distributions for each combination of von Bertalanffy parameters. The closeness of VBGF parameters between A and B areas was evaluated by computing the phi-prime index (Φ') of Pauly and Munro (1984). As regards the statistical treatments, different test were implemented according to Sokal and Rolf (1995); in particular, the Shapiro-Wilk and F-tests were applied to verify the assumptions of data distribution normality and homogeneity of variances, paired t-test to compare the biological parameters (given the likely dependence of the stock of the two areas) and, finally, the Kolmogorov-Smirnov (K-S) test was used for LFDs comparison.

RESULTS

Both published and new elaborated data indicate a wide distribution of the African armoured searobin with a marked and significant high frequency of occurrence (Paired t-test, $p < 0.01$) and abundance (Wilcoxon test; $p < 0.05$) in the B-area (Fig. 2; Tab. II). The Sr (Tab. III) ranged between 0.38 and 0.48 (A-area) and between 0.42 and 0.50 (B-area); males resulted predominant in both areas and in spite of the closeness of the overall estimators (0.42 and 0.46, respectively for A- and B-area) the difference resulted highly significant (Wilcoxon test, $p < 0.01$).

The median length of fully mature specimens (stage 4) in both sexes, as well as the mean length, was quite similar in the two investigated areas, with no significant differences (Paired t-test, $p > 0.05$; see Tab. III and Fig. 3)

As concern the size at onset of sexual maturity (L_m), in the B-area the stock showed a slight precocious maturity than the A-area (183 *vs* 191mm and 199 *vs* 212 mm, for females and males, respectively); however this difference was not significant in both females (Wilcoxon test, $p > 0.05$) and males (Paired t-test, $p > 0.05$; see Figs 3, 4 and Tab. III).

As regards the length structure, the specimens (sex combined) ranged from 40 to 320 mm and from 40 to 300 mm

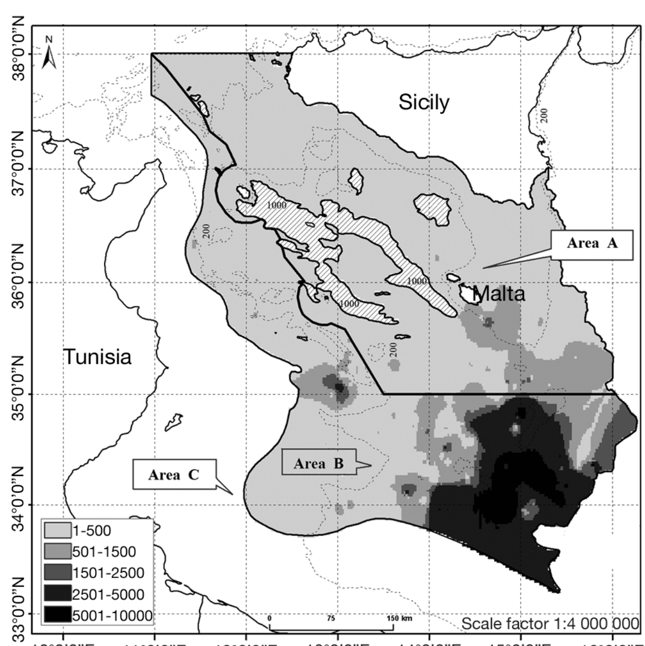

Figure 2. - Spatial representation of the density index (DI; N*km^{-2}) of *Peristedion cataphractum* for the A- and B-area the South Sicily and North Africa.

Table II. - Comparison of abundance and length frequency distribution (LFD) of *Peristedion cataphractum* in A and B areas. Mean density (DI: $N*km^{-2}$) and biomass (BI: $kg.km^{-2}$) indexes, and frequency of occurrence (f), refers to the preferential depth range (201-500 m). WT: Wilcoxon test; PT: Paired t-test; KS: Kolmogorov Smirnov test; Significance level: * = 0.05, ** = 0.01.

Parameter	Area	Sex	1997	1998	2000	2001	2003	2004	Overall	Test	Significance level
DI	A	C	19	34	16	49	227	108	75	WT-5.39	*
	B		1186	1416	651	844	537	632	878		
BI	A	C	0.6	1.6	0.6	1.0	10.6	5.9	3.4	WT-4.77	*
	B		63.0	73.0	32.7	40.8	23.4	23.3	42.7		
f%	A	C	44	54	42	56	70	54	53.2	PT-49.8	**
	B		89	94	92	98	87	80	89.9		
LFD	A *vs* B	C	0.2	0.3	0.3	0.2	0.2	0.3		K-S	always **

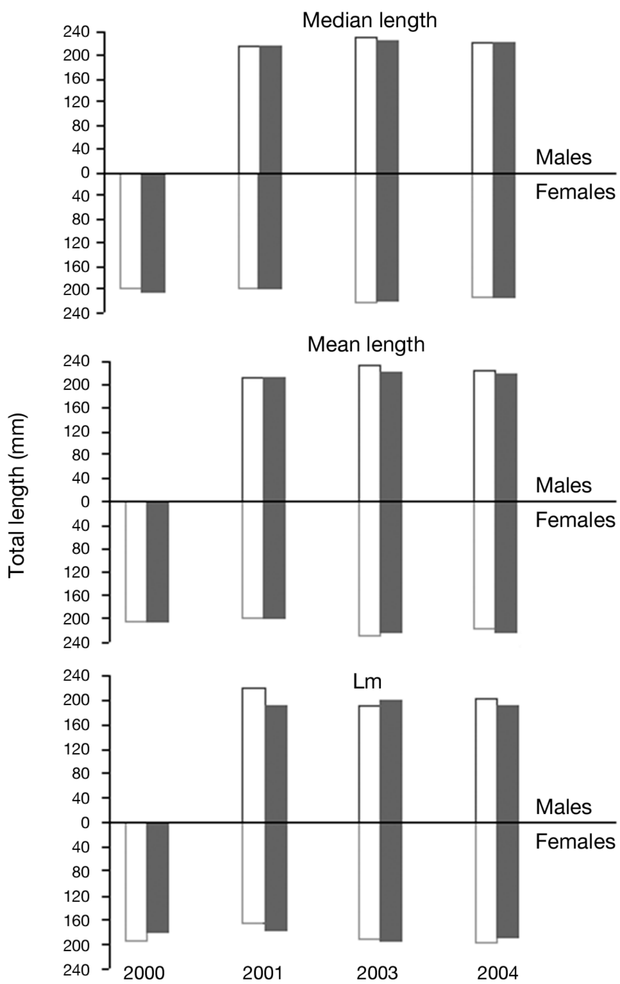

Figure 3. - Median and mean length (total, mm) of fully mature *Peristedion cataphractum* specimens and length at the onset of maturity (Lm) by sex and area (solid: A-area; empty: B- area).

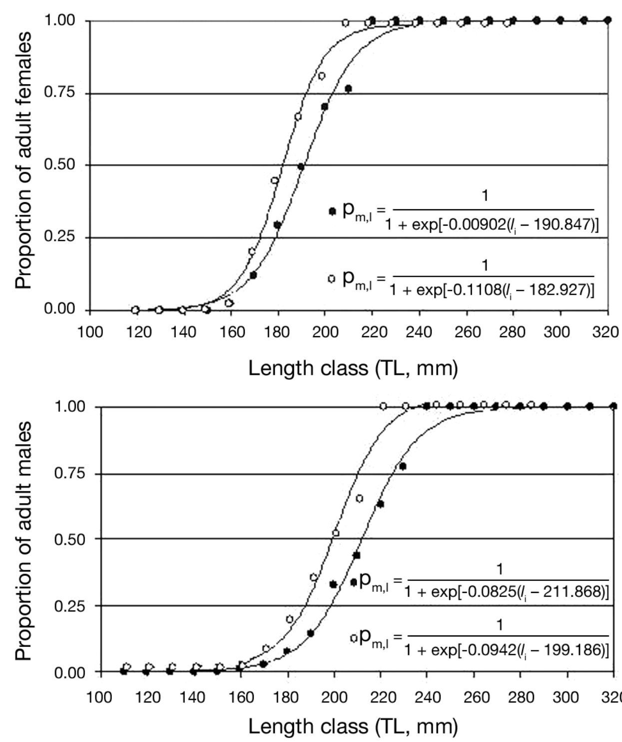

Figure 4. - Overall (years combined) proportions of adult *Peristedion cataphractum* specimens by size class and sex in the two areas with over imposed the logistic fit and corresponding estimated coefficients. Solid and empty dots denote A and B areas, respectively.

for the stock of A- and B-area, respectively. The LFD shape (Fig. 5), was characterized by modes well distinguished among the smaller size classes, reflecting discrete recruitment and then merged at older ages. The K-S test revealed significant ($p < 0.01$) differences between the two stocks (Tab. II) mainly due to different consistence of size classes ranging from 160 to 230 mm TL.

Finally, similar von Bertalanffy growth parameters resulted for stock of the A- (L_∞ = 379 mm, Ky^{-1} = 0.38, t_{0y} = -0.44; max score: 34.8) and B-area (L_∞ = 390 mm, Ky^{-1} = 0.36, t_{0y} = -0.44; max score = 214) with a practical coincident phi-prime (4.737 and 4.738 for A- and B-area, respectively).

Table III. - Comparison of sex ratio (Sr) and size at maturity (Md; Mn; Lm) of *Peristedion cataphractum* between A and B areas. Sr: sex ratio; Md and Mn: median and mean total length at full maturity stage; Lm: size at 50% of maturity; WT: Wilcoxon test; PT: Paired t-test; Significance level: ns = not significant, * = 0.05, ** = 0.01. Ne: parameter not estimated.

			Survey						
Parameter	Area	Sex	2000	2001	2003	2004	Overall	Test	Significance level
Sr	A		0.41	0.38	0.42	0.48	0.42	PT-6.5	**
	B		0.47	0.42	0.48	0.5	0.47		
Md	A	F	200	200	225	215	200	PT-0	ns
	B	F	205	200	220	215	200		
	A	M	-	215	230	220	215	PT-1.41	ns
	B	M	-	215	225	220	215		
Mm	A	F	203	200	228	218	205	PT-0.16	ns
	B	F	204	200	221	222	204		
	A	M	-	214	232	224	215	PT-1.99	ns
	B	M	-	214	222	217	215		
Lm	A	F	194	168	193	196	191	WT-5	ns
	B	F	183	177	194	190	183		
	A	M	ne	221	191	202	212	PT-1.19	ns
	B	M	ne	191	198	190	199		

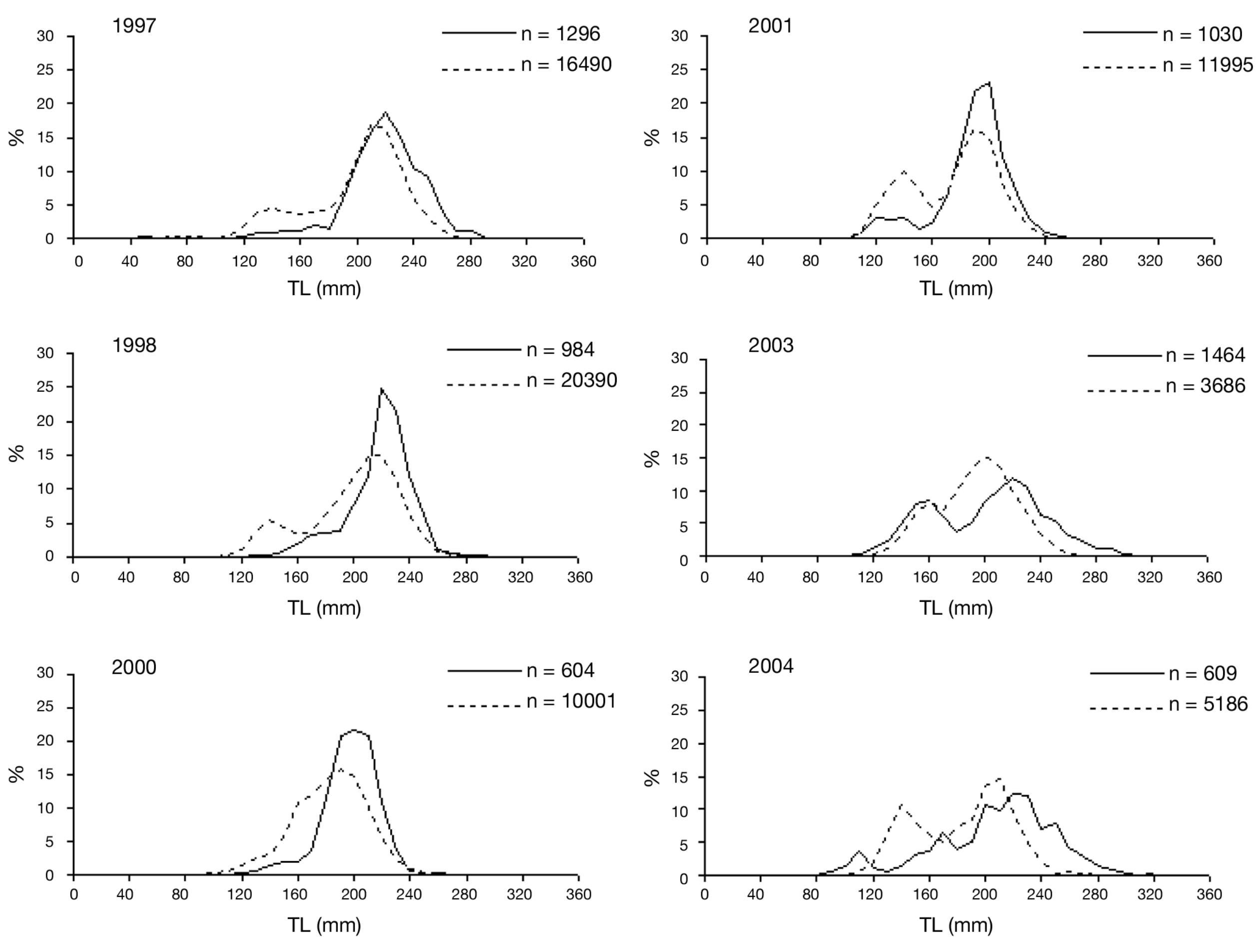

Figure 5. - Relative (%) total length (TL) frequency distributions by survey and area of *Peristedion cataphractum* (sex combined). Dotted and continuous lines refer to the A and B areas, respectively.

DISCUSSION

Present contribution supports the hypothesis of common biological features of the African armoured searobin populations in the two areas. However, the large difference in abundance and length structures also suggest maintaining distinct the two unit stocks since the low rate of spatial interchange likely as a consequence of the sedentary behaviour and low mobility of the species. Obviously, a proper and more robust identification of stock would require more experimental studies such as tagging and genetic techniques (Rodrìguez-Cabello *et al.*, 2004). As regards the Mediterranean stocks, morphometric and genetic studies have been applied to anchovy (Tudela *et al.*, 1999), hake (Roldán *et al.*, 1998), Norway lobster (Castro *et al.*, 1998; Maltagliati *et al.*, 1998) and red shrimp (Sardà *et al.*, 1998). However, Lleonart and Maynou (2003) considered most of these studies as "non conclusive" at least from a fishing operative point of view.

In a data limited context, unit stock definition *sensu* Gulland (1983) represents an important step in the assessment and management path for a rational exploitation of the fished marine living resources especially when there are evidences of a differential distribution of fishing effort as seems the case for the Strait of Sicily (Garofalo *et al.*, 2003; Gristina *et al.*, 2006; Dimech *et al.*, 2008).

In the case of the African armoured searobin, as well as for the other Mediterranean demersal resources, the absence of significant geographic barriers, the homeothermia of the water, the lack of information prior the exploitation phase frequently makes little conclusive the experimental approach.

In this study the abundance of African armoured searobin is resulted quite higher in the B- than A-area. In particular, higher abundance zone is located on the south-eastern zone where fishing effort is reported to be less than in contiguous area. This area, near to the Maltese exclusive fishing zone where the bottom trawling is limited, is characterized by lower levels of fishing effort in respect with the contiguous areas (Garofalo *et al.*, 2003; Gristina *et al.*, 2006; Dimech *et al.*, 2008).

A similar distribution pattern has already been reported for other demersal sedentary species. Specifically, Garofalo *et al.* (2003) have showed the high asymmetric horizontal distribution of some rays and related it to heterogeneous trawling effort that characterized the Strait of Sicily.

Although it is difficult to separate the effect of fishing from other variables (Anderson *et al.*, 2008), environmental conditions of two studied area as depth, temperature, bottom type, and oceanographic features can be considered as comparable (Gristina *et al.*, 2006; Ragonese *et al.*, 2008). Hence, the observed differences in abundance are consistent with the effects of fishing rather than environmental process.

Median length and mean length of fully mature specimens, and the von Bertalanffy growth parameters showed an almost fully "biological" coincidence between the two areas. On the contrary, the significant differences in sex ratio and size at maturity are in agreement with the differentials in the size structure.

An interesting aspect of the present study is the homogeneity of demographic parameters despite the high differences in abundance between the two areas. This is in contrast with theories involving a phenotypic plasticity in response to fishing (Rochet, 2000; Hutchings, 2005; Kuparinen and Merilä, 2007), for example, the reduction of the size at sexual maturity with increasing exploitation.

The stability of parameters is also in contrast with trophic enrichment (Caddy, 1993) and warming of the Mediterranean Sea that would contribute to the "tropicalization" of demersal resources (Stergiou, 2002). Although there are evidences of a reduction in continuity and entity of warming (Vargas-Yáñez *et al.*, 2009), an explanation could be that the population of the Strait of Sicily has already passed the optimal point of exploitation before the present considered period and is gradually moving towards a progressive exhaustion (i.e., the smooth collapse pattern described in Mullon *et al.*, 2005). As matter of fact, the Strait of Sicily is an overexploited area where the maximum sustainable yield had been passed over in late seventies – early eighties (Levi and Andreoli, 1989) and for which the slow decline of demersal resources, as well as changes in fish assemblages in relation to exploitation levels have been progressed continuously (Levi *et al.*, 1998; Gristina *et al.*, 2006).

The two stock assumption hence seems the best operative approach given that the A- and B-areas require different management actions: a strong rebuilding in the A-area *vs* a moderate protection in the B-area.

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